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5TH ANNUAL INTERNATIONAL CONFERENCE ON ARCHITECTURE & CIVIL ENGINEERING

SINGAPORE, 8-9 MAY 2017

THE INFLUENCE OF ARCHITECTURAL TECHNOLOGISTS ON CONSTRUCTION ERGONOMICS

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Introduction (1)

- The South African Construction Regulations (2014) state that during the design stage, designers must take cognisance of ergonomic design principles in order to minimize ergonomic related hazards in all phases of the life cycle of a structure
- Amplifies the need for 'designing for safety', which Behm (2006) defines as "The consideration of construction site safety in the preparation of plans and specifications for construction projects"
- Thorpe (2006) states that there is no more important stage in the construction process than that of design, as at this stage conceptual ideas are converted into constructable realities:
  - 'Designing for H&S' being one of the designing for constructability principles

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Introduction (2)

  - A variety of considerations need to be balanced simultaneously, inter alia, designing for H&S, which is an integral part of the wider design process
  - Therefore, needs to be included in design planning as doing so will result in safer construction and maintenance of structures and facilities
- Hecker *et al.* (2006) contend that H&S through design is a fundamental principle of ergonomics:
  - Architects and engineers regularly address ergonomics in their designs, but the concerns apply almost exclusively to the end-user of a facility, rather than the workers who construct it
- Gambatese (1998) states that historically, the design professions have not addressed construction H&S

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Introduction (3)

- The aforementioned highlight the relevance of designing for H&S and ergonomics, and the rationale for the study reported on, the objectives being to determine the:
  - Importance of project parameters to architectural technologists;
  - Importance of ergonomics during the various project phases to architectural technologists
  - Frequency at which architectural technologists consider construction ergonomics on various occasions and relative to various design related aspects
  - Extent to which various design related aspects impact on construction ergonomics
  - Source of ergonomics knowledge
  - Potential of various aspects to contribute to an improvement in construction ergonomics
  - Degree of awareness relative to certain provisions of the Occupational Health and Safety Act (OH&S Act) and the Construction Regulations

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Construction Regulations (1)

Clients required to:

- **5 (1) (a) Prepare a baseline risk assessment (BRA)**
- **5 (1) (b) Prepare an H&S specification based on the BRA**
- **5 (1) (c) Provide the designer with the H&S specification**
- **5 (1) (d) Ensure that the designer takes the H&S specification into account during design**
- **5 (1) (e) Ensure that the designer carries out the duties in Regulation 6 'Duties of designers'**
- **5 (1) (f) Include the H&S specification in the tender documents (Republic of South Africa, 2014)**

Regrettably, it is not stated that the H&S specification must be revised to include amendments required in terms of the designer report

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Construction Regulations (2)

Designers of a structure must:

- (a) ensure that the H&S standards incorporated into the regulations are complied with in the design
- (b) take the H&S specification into consideration
- (c) include in a report to the client before tender stage:
  - all relevant H&S information about the design that may affect the pricing of the work
  - the geotechnical-science aspects
  - the loading that the structure is designed to withstand
- (d) inform the client of any known or anticipated dangers or hazards relating to the construction work, and make available all relevant information required for the safe execution of the work upon being designed or when the design is changed

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Construction Regulations (3)

- (e) modify the design or make use of substitute materials where the design necessitates the use of dangerous procedures or materials hazardous to H&S
- (f) consider hazards relating to subsequent maintenance of the structure and make provision in the design for that work to be performed to minimize the risk (Republic of South Africa, 2014)

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Designing for construction ergonomics

Hecker *et al.* (2006):

- **Contend that H&S through design is a fundamental principle of ergonomics, and that the hierarchy of controls is fundamental to the process of hazard reduction i.e. elimination or substitution to mitigate hazards**
- **Although architects and engineers regularly address ergonomics in their designs, they do so almost exclusively relatively to the end-user of a facility, rather than the workers who undertake the construction thereof**

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Impact of designers on construction ergonomics

- **Behm (2006) analysed 450 reports of construction workers' deaths and disabling injuries in the USA - in 151 cases (33.6%), the hazard that contributed to the incident could have been eliminated or reduced if 'design-for-H&S' measures had been implemented**

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Obstacles to designing for construction ergonomics

- **Hecker *et al.* (2006) cite the following:**
  - **The narrow specialisation of design and construction practice**
  - **Limited pre-construction collaboration between the designer and constructor due to the traditional construction procurement system (TCPS)**
  - **The limited availability of ergonomics-in-design tools, guidelines and procedures**
  - **Limited education architects and engineers receive regarding construction ergonomics**
- **Construction Industry Development Board (cidb) (2009) report states that at the tertiary level, not all construction related programmes in South Africa include H&S within their curricula, especially designer programmes**

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Potential of designers to contribute to construction ergonomics

South African built environment practitioners (Smallwood, 2006a) - the extent in terms of a mean score ranging between 1.00 and 5.00 is:

- **Constructability (general) (4.53)**
- **Awareness (4.52)**
- **Mechanisation (4.45)**
- **Prefabrication (4.31)**
- **General design (4.22)**
- **Reengineering (4.19)**
- **Specification (4.09)**
- **Details (4.03)**

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Importance of H&S / ergonomics

- Historically, cost, quality, and time, have taken precedence over H&S in terms of the importance of project parameters
- An 'image of contractors' study conducted among clients by Smallwood (2010) required respondents to indicate the importance of twenty-six image related aspects. The mean scores recorded between parentheses are between 1.00 (lower limit) and 5.00 (upper limit)
    - Quality (4.75) and remaining within budget (4.75) ranked joint 1st
    - Time performance (4.25) 8th
    - Health (4.00) 11th
    - Safety (3.75) 13th

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Accidents and related issues (1)

- Schwartz (1995) cites a traffic engineer's contention that there is no such a thing as a true accident
- An accident is a result of human or mechanical failure, or a combination of both – nothing happens without a cause
- Mainstream literature, invariably defines an accident as an unplanned event
- Given that management is responsible for planning, organising, leading, controlling, and coordinating, and accidents are unplanned events, then accidents effectively constitute a failure of management
- Hinze (2006) contends that all accidents are preventable and that construction is not inherently dangerous

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Accidents and related issues (2)

- Strategies, systems, procedures, and protocol can mitigate or eliminate ‘accidents’
- A multi-stakeholder approach and ‘designing for H&S’ are examples of strategies
- Documented H&S management systems and quality management systems are examples of systems
- The provision of an H&S specification to designers by clients, a report to clients by designers, and the provision of an H&S specification to the PC is an example of a procedure. Design HIRAs are a further example
- The protocol of including H&S as the first item on a project progress meeting agenda raises the status of H&S

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The Cost of Accidents (COA) and the benefits of optimum H&S

- Costs:
  - COA is estimated to be between 4.3% and 5.4% of the value of completed construction
  - Cost of implementing H&S is estimated to be between 0.5% and 3% of project costs
  - Clearly H&S is a 'profit centre' (Smallwood, 2004)
- The synergy between construction H&S and the other eleven project parameters results in further financial benefits: environment; cost; developmental criteria; environment; productivity; public H&S; quality; time; client satisfaction; design team satisfaction, and worker satisfaction (Smallwood, 2006b)

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Reduction of risk through design and specification (1)

(Steel Construction, 2004)

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Reduction of risk through design and specification (2)

(Steel Construction, 2004)

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Reduction of risk through design and specification (3)

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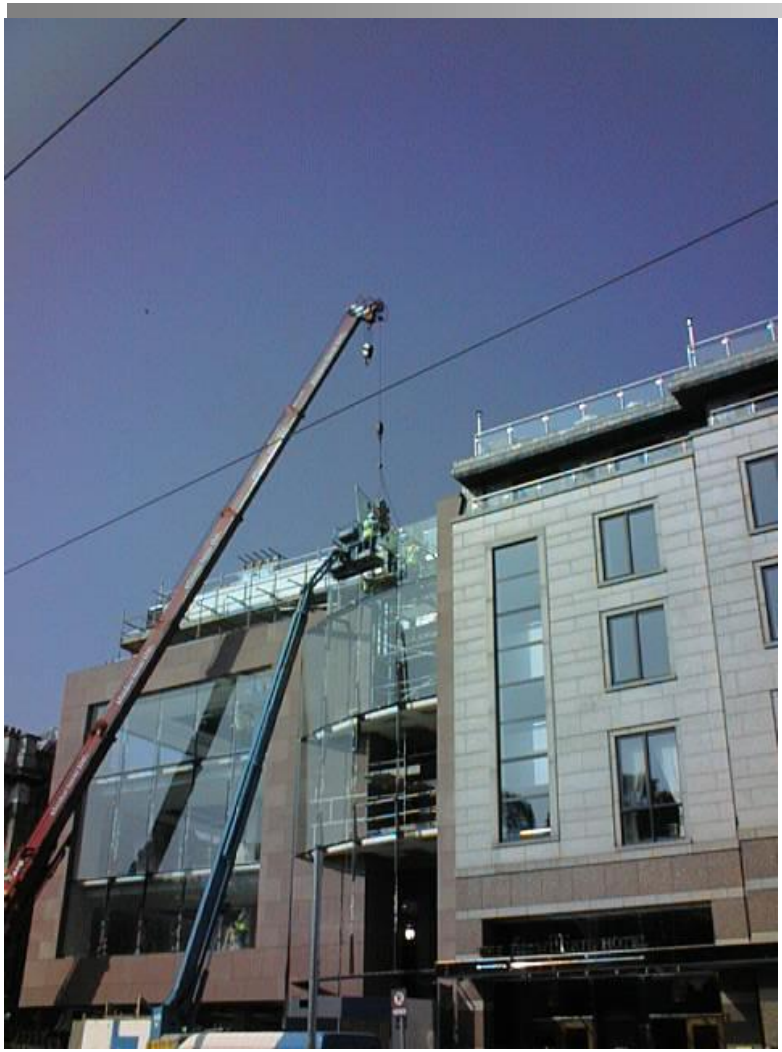
Reduction of risk through design and specification (4)



Externally installed full fenestration, Dublin (Smallwood, 2004)

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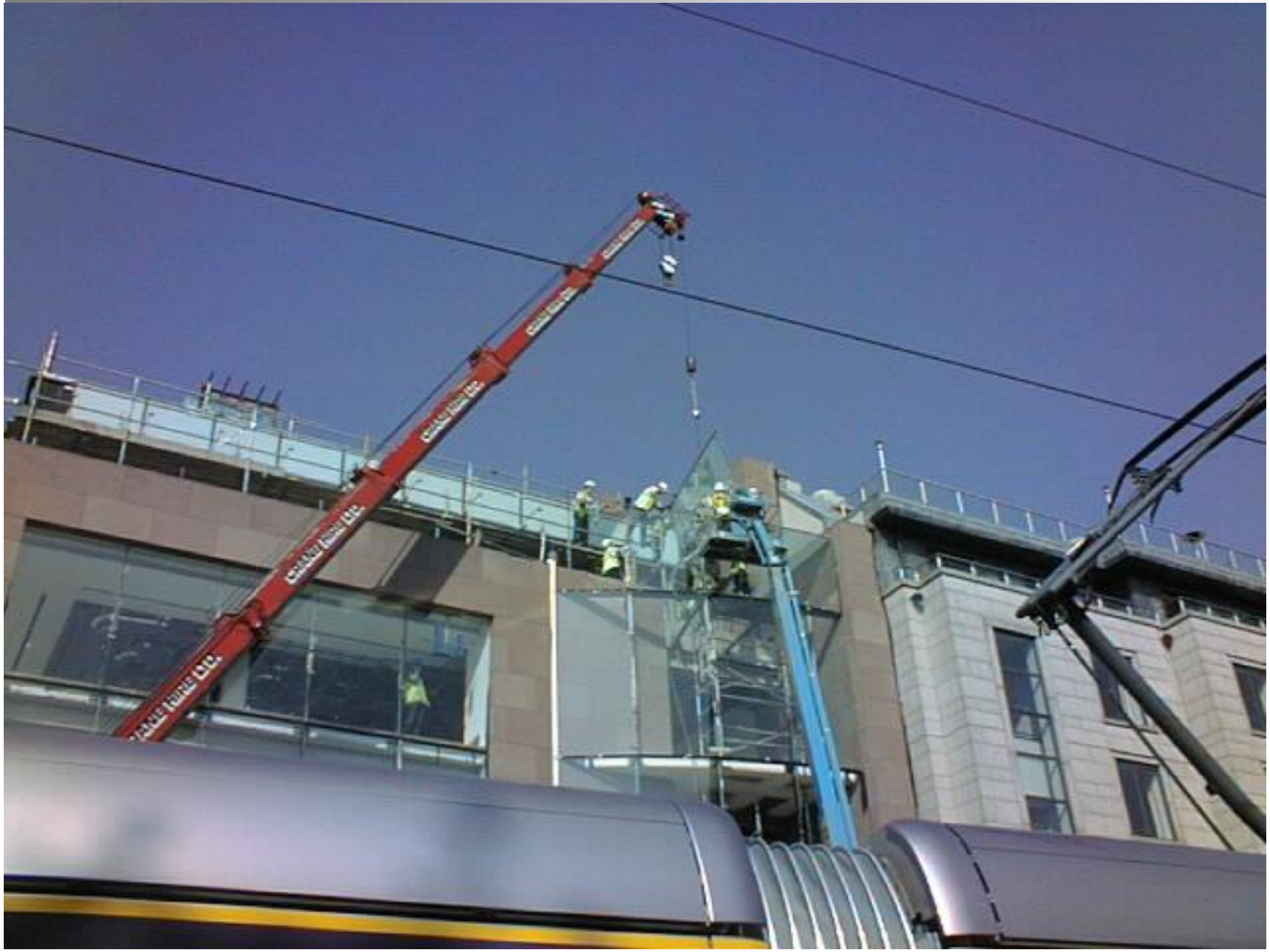
Reduction of risk through design and specification (5)



Externally installed full fenestration, Dublin (Smallwood, 2004)

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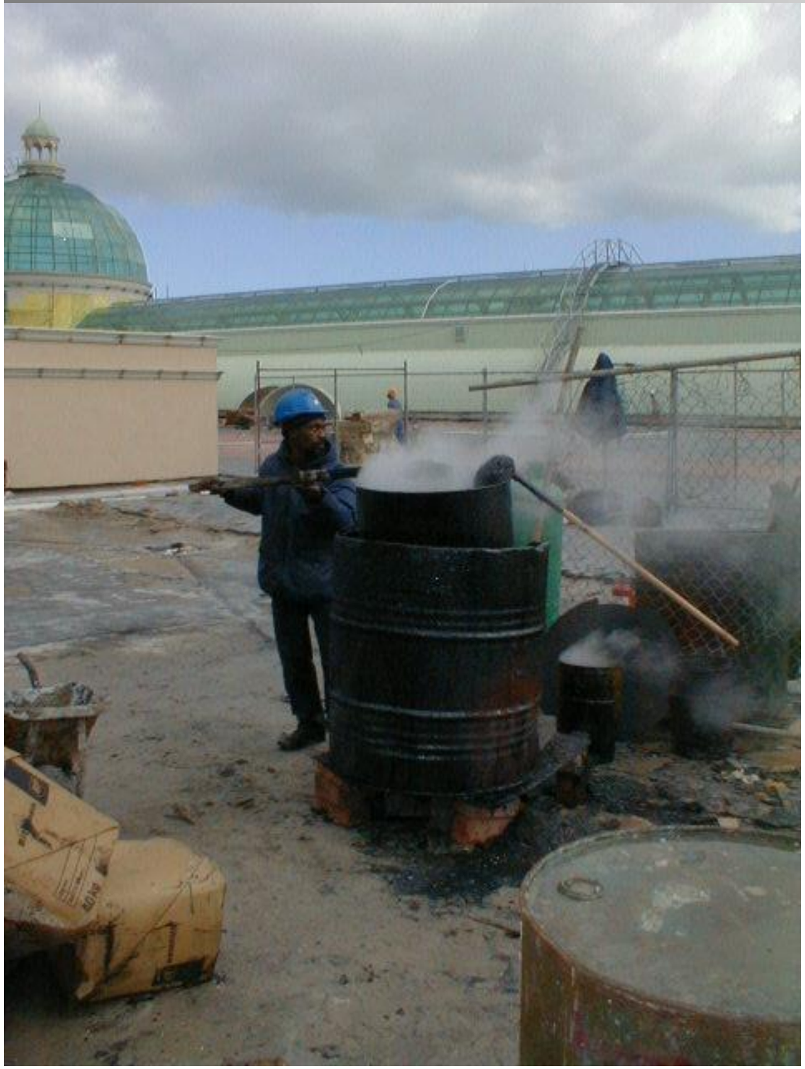
Reduction of risk through design and specification (6)



'Melting' mastic asphalt, Canal Walk, Cape Town (Smallwood, 2000)

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Research – Sample stratum and method

- 492 members of the South African Institute of Architectural Technologists (SAIAT)
- Surveyed per post
- 37 Responses were included in the analysis of the data
- Due to eleven questionnaires not being delivered and one recipient's non-availability to respond, the net sample size was 480
- Response rate is 7.7% [37 / (492 – 12)]
- The analysis of the data consisted of the calculation of descriptive statistics to depict the frequency distribution, and a measure of central tendency (MS) of responses to fixed response questions

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Research – Findings (1)

Parameter	Response (%)						MS	Rank
	Un-sure	Not ……………………………………Very						
		1	2	3	4	5		
Project quality	0.0	0.0	2.7	2.7	27.0	67.6	4.59	1
Environment	0.0	0.0	0.0	10.8	29.7	59.5	4.49	2
End-user ergonomics*	2.7	0.0	0.0	2.7	35.1	59.5	4.46	3
Project time	0.0	0.0	2.7	13.5	27.0	56.8	4.38	4
Project cost	0.0	0.0	2.7	8.1	40.5	48.6	4.35	5
Project health and safety (H&S)	2.7	0.0	2.7	21.6	16.2	56.8	4.19	6
Construction ergonomics*	0.0	0.0	10.8	24.3	27.0	37.8	3.92	7

Table 1: Importance of project parameters to Architectural Technologists (MS = 1.00 – 5.00).

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Research – Findings (2)

Phase	Response (%)						MS	Rank
	Un-sure	Not ……………………………….Very						
		1	2	3	4	5		
Use	2.7	0.0	2.7	8.1	16.2	70.3	4.46	1
Maintenance	2.9	2.9	0.0	14.3	31.4	48.6	4.14	2
Construction	2.7	2.7	10.8	24.3	32.4	27.0	3.62	3
Commissioning	5.4	0.0	21.6	16.2	32.4	24.3	3.43	4
Deconstruction	13.5	8.1	16.2	29.7	16.2	16.2	2.76	5

Table 2: Importance of ergonomics to Architectural Technologists during various building / structure phases (MS = 1.00 – 5.00).

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Research – Findings (3)

Occasion (Stream)	Response (%)						MS	Rank
	Unsure	Never	Rarely	Sometimes	Often	Always		
Working drawings (Up)	0.0	2.7	8.1	35.1	48.6	2.7	3.32	1
Detailed design (Up)	0.0	2.7	8.1	35.1	51.4	0.0	3.30	2
Concept design (Up)	0.0	5.4	0.0	45.9	43.2	2.7	3.30	3
Site inspections / discussions (Down)	0.0	5.4	16.2	48.6	21.6	2.7	2.84	4
Preparing project documentation (Mid)	2.7	5.4	32.4	27.0	32.4	0.0	2.81	5
Site meetings (Down)	0.0	5.4	32.4	37.8	18.9	2.7	2.73	6
Design coordination meetings (Up)	2.7	13.5	8.1	56.8	16.2	0.0	2.65	7
Client meetings (Up)	0.0	10.8	32.4	27.0	24.3	0.0	2.54	8
Constructability reviews (Up)	5.4	10.8	32.4	29.7	18.9	0.0	2.41	9
Site handover (Mid)	8.1	16.2	13.5	32.4	18.9	0.0	2.16	10
Pre-qualifying contractors (Mid)	10.8	8.1	27.0	27.0	13.5	0.0	1.97	11
Deliberating project duration (Up)	10.8	18.9	27.0	27.0	8.1	0.0	1.86	12
Evaluating tenders (Mid)	8.1	16.2	21.6	24.3	13.5	0.0	1.86	13
Pre-tender meeting (Mid)	10.8	18.9	29.7	18.9	10.8	0.0	1.78	14

Table 3: Frequency at which Architectural Technologists consider / refer to construction ergonomics on various occasions (MS = 1.00 – 5.00).

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Research – Findings (4)

Aspect	Response (%)						MS	Rank
	Unsure	Never	Rarely	Sometimes	Often	Always		
Design (general)	0.0	8.1	8.1	24.3	56.8	2.7	3.38	1
Plan layout	0.0	2.7	10.8	24.3	56.8	2.7	3.38	2
Elevations	0.0	5.4	13.5	29.7	48.6	0.0	3.16	3
Method of fixing	0.0	10.8	16.2	32.4	40.5	0.0	3.03	4
Specification	0.0	8.3	13.9	36.1	38.9	0.0	3.00	5
Details	0.0	8.1	24.3	29.7	37.8	0.0	2.97	6
Position of components	0.0	8.1	16.2	35.1	37.8	0.0	2.97	7
Site location	2.7	8.1	18.9	24.3	40.5	2.7	2.95	8
Type of structural frame	0.0	2.7	24.3	51.4	21.6	0.0	2.92	9
Schedule	0.0	11.1	11.1	41.7	30.6	0.0	2.81	10
Finishes	2.7	10.8	21.6	37.8	24.3	0.0	2.65	11
Edge of materials	2.7	16.2	18.9	29.7	29.7	0.0	2.62	12
Content of material	0.0	16.2	16.2	43.2	18.9	0.0	2.54	13
Surface area of materials	0.0	13.5	27.0	32.4	18.9	0.0	2.41	14
Texture of materials	0.0	13.5	24.3	40.5	13.5	0.0	2.38	15
Mass of materials	2.7	8.1	51.4	27.0	10.8	0.0	2.35	16

Table 4: Frequency at which Architectural Technologists consider / refer to construction ergonomics relative to various design related aspects (MS = 1.00 – 5.00).

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Research – Findings (5)

Aspect	Response (%)							MS	Rank
	Un-sure	Does not	Minor………………………... Major						
			1	2	3	4	5		
Site location	2.7	2.7	2.7	5.4	10.8	24.3	51.4	4.11	1
Design (general)	2.7	2.7	0.0	5.4	10.8	37.8	40.5	4.08	2
Plan layout	2.7	5.4	0.0	2.7	16.2	21.6	51.4	4.08	3
Details	0.0	0.0	2.7	2.7	18.9	37.8	37.8	4.05	4
Position of components	2.8	0.0	0.0	8.3	16.7	36.1	36.1	4.03	5
Edge of materials	8.1	0.0	2.7	8.1	21.6	18.9	40.5	3.94	6
Type of structural frame	2.7	0.0	2.7	10.8	16.2	32.4	35.1	3.89	7
Finishes	5.4	0.0	5.4	5.4	21.6	27.0	35.1	3.86	8
Method of fixing	2.7	0.0	8.1	8.1	16.2	24.3	40.5	3.83	9
Elevations	2.7	5.4	0.0	8.1	16.2	32.4	35.1	3.81	10
Specification	0.0	0.0	8.1	5.4	24.3	32.4	29.7	3.70	11
Mass of materials	8.1	0.0	8.1	8.1	13.5	40.5	21.6	3.65	12
Schedule	5.4	2.7	5.4	8.1	21.6	29.7	27.0	3.60	13
Texture of materials	2.7	0.0	8.1	10.8	24.3	27.0	27.0	3.56	14
Surface area of materials	5.4	2.7	10.8	10.8	18.9	18.9	32.4	3.46	15
Content of material	2.7	2.7	8.1	13.5	16.2	32.4	24.3	3.44	16

Table 5: Extent to which various design related aspects impact on construction ergonomics (MS = 0.00 – 5.00).

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Research – Findings (6)

Aspect	Impact		Consider / Refer	
	MS	Rank	MS	Rank
Site location	4.11	1	2.95	8
Design (general)	4.08	2	3.38	1
Plan layout	4.08	3	3.38	2
Details	4.05	4	2.97	6
Position of components	4.03	5	2.97	7
Edge of materials	3.94	6	2.62	12
Type of structural frame	3.89	7	2.92	9
Finishes	3.86	8	2.65	11
Method of fixing	3.83	9	3.03	4
Elevations	3.81	10	3.16	3
Specification	3.70	11	3.00	5
Mass of materials	3.65	12	2.35	16
Schedule	3.60	13	2.81	10
Texture of materials	3.56	14	2.38	15
Surface area of materials	3.46	15	2.41	14
Content of material	3.44	16	2.54	13

Table 6: Comparison of the extent to which various design related aspects impact on construction ergonomics versus the frequency at which respondents consider / refer to such aspects.

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Research – Findings (7)

Factor	Unsure	Response (%) Minor………… Major 1	2	3	4	5	MS	Rank
Safe working procedures (C)	2.7	2.7	0.0	10.8	21.6	62.2	4.44	1
General design (D)	0.0	0.0	0.0	13.5	32.4	54.1	4.41	2
Awareness (C & D)	2.7	0.0	5.4	8.1	35.1	48.6	4.31	3
Constructability (general) (D)	0.0	0.0	8.3	11.1	41.7	38.9	4.11	4
Details (D)	0.0	0.0	5.6	16.7	44.4	33.3	4.08	5
Contractor planning (C)	2.7	2.7	10.8	8.1	35.1	40.5	4.03	6
Design of construction equipment (C)	5.7	0.0	11.4	14.3	37.1	31.4	3.94	7
Specification (D)	2.8	5.6	5.6	19.4	33.3	33.3	3.86	8
Reengineering (C, D & P)	19.4	2.8	11.1	16.7	22.2	27.8	3.76	9
Design of tools (C)	5.6	0.0	19.4	13.9	36.1	25.0	3.71	10
Prefabrication (D)	0.0	2.8	11.1	27.8	33.3	25.0	3.67	11
Mechanisation (C & D)	11.1	2.8	16.7	13.9	30.6	25.0	3.66	12
Workshops on site (C)	0.0	8.3	11.1	16.7	36.1	27.8	3.64	13

Table 7: Potential of various aspects / interventions to contribute to an improvement in construction ergonomics during the various project phases (MS = 0.00 – 5.00).

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Research – Findings (8)

Source	Yes (%)
Experience	83.8
Tertiary education	43.2
Magazine articles	40.5
Journal papers	18.9
Other	18.9
Practice notes	16.2
Post graduate qualifications	10.8
Workshops	10.8
Conference papers	8.1
CPD seminars	0.0

Table 8: Respondents' source of ergonomics knowledge.

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Research – Findings (9)

- Only 30.6% of respondents were aware of the provisions of Section 10 of the OH&S Act of 1993, 52.8% were not, and 16.7% were unsure:
  - Only 54.5% of those that were aware could communicate a synopsis of the content thereof
- 25% of respondents were aware of the ergonomics related provisions of the Construction Regulations, 55.6% were not, and 19.4% were unsure:
  - Only 22.2% of those that were aware could communicate a synopsis of the content thereof

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Conclusions (1)

- Quality, cost and time are more important than project H&S and construction ergonomics → architectural technologists do not understand and appreciate the synergy between project H&S and ergonomics, and the other parameters
- Construction ergonomics is less important than ergonomics during the maintenance and commissioning phases → the focus on ergonomics by architectural technologists is likely to be more in the latter phases than during construction
- Architectural technologists do consider construction ergonomics on various occasions, however, more so during upstream phases than mid-stream phases → cited importance of ergonomics does manifest itself (MS = 3.92 / 5.00)

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Conclusions (2)

- Architectural technologists consider construction ergonomics on various design related occasions - rarely to sometimes / sometimes (75%), and between never to rarely / rarely (25%) → cited importance of ergonomics does manifest itself (MS = 3.92 / 5.00)
- Architectural technologists do appreciate the extent to which various design related aspects impact on construction ergonomics (design related aspects have between an impact to near major impact / near major impact thereon)
- Divergent rankings between the perceived impact of design related aspects on construction ergonomics, and the consideration / reference to such aspects →

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Conclusions (3)

architectural technologists' actions are not always based on a structured process such as documented design hazard identification and risk assessment

- Sources of architectural technologists' ergonomics knowledge →:
  - Sources are more informal than formal – experience vis-à-vis tertiary education
  - Tertiary architectural technologist education and the architectural technologist profession are not addressing ergonomics to the extent that they should
- Perceived potential of various aspects / interventions to contribute to an improvement in construction ergonomics → architectural technologists do appreciate the potential of various design, procurement and construction practices to contribute to an improvement in construction ergonomics

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Conclusions (4)

- Given the low level of awareness relative to certain provisions of the Occupational Health and Safety Act and the Construction Regulations → tertiary architectural technologist education and the architectural technologist profession is not addressing construction ergonomics to the extent that they should

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Recommendations

- Tertiary architectural technologist education should address construction H&S and ergonomics, and highlight the role thereof in overall project performance
- Designing for construction H&S and ergonomics should be introduced and more importantly, embedded in tertiary architectural technologist education programmes.
- The South African Institute of Architectural Technologists (SAIAT) should evolve construction H&S and ergonomics practice notes, and promote continuing professional development relative to construction H&S and ergonomics
- Ergonomics Regulations should be promulgated. In fact, the Draft Ergonomics Regulations were published for public comment on 27 January 2017 after the study reported on was conducted

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